PAN-PACIFIC ENTOMOLOGIST
65(4), 1989, pp. 397–402

Reproductive Compatibility in Widely Separated Populations of Three Species of Phytoseiid Mites (Acari: Phytoseiidae)

J. A. McMurtry and M. H. Badii[1]

Department of Entomology, University of California, Riverside, California 92521.

Abstract.—Cross-breeding experiments showed reproductive compatibility (production of ♀ and ♂ progeny) between a California population of *Neoseiulus californicus* and populations of *N.* "*chilenensis*" from either Chile or Peru. The results supported previous opinions that *chilenensis* is a synonym of *californicus.* Reproductive compatibility (based on parental crosses and F_1 backcrosses) also was shown between populations of *Phytoseiulus macropilis* from California and Cook Islands and *Typhlodromus annectens* from California (CA) and Mexico (MX), although in the latter species, the CA ♀ × MX ♂ parental cross resulted only in ♂ progeny. The results are discussed in relation to other such studies in the Phytoseiidae.

Both native and exotic species of Phytoseiidae are utilized in the biological control of phytophagous mites (McMurtry, 1982). Sources of collections and/or cultures of these predaceous mites used in research programs may have originated from two or more widely separated geographic areas. Specimens from the different areas may appear identical or they may show slight but consistent morphological differences, especially in setal lengths. On the basis of external morphology alone, it may be impossible to decide whether two or more populations are conspecific or if they have diverged to the point where they are reproductively isolated and should be considered separate species.

Laboratory cross-breeding tests to determine the degree of reproductive compatibility between populations can aid in making taxonomic decisions. For example, two populations of *Amblyseius potentillae* Garman, one from Italy and one from The Netherlands, showed both morphological and biological differences, but no reproductive barriers were evident in laboratory tests (McMurtry et al., 1976). On the other hand, biosystematic studies of an *Euseius* complex from Mexico and Central America (McMurtry et al., 1985) and California (Congdon and McMurtry, 1985, 1986), and *Typhlodromus* species in the *pini* group (Mahr and McMurtry, 1979), have indicated the existence of both allopatric and sympatric species distinguishable morphologically by only small differences, mainly in setal lengths. Intraspecific variation in these subtle differences may be as great

[1] Present address: Universidad Autónoma de Nuevo León, Faculdad Ciencias Biologicas, San Nicolás de los Garza, N.L., Mexico.

as interspecific variation within some species groups (Mahr, 1979; Mahr and McMurtry, 1979; McMurtry, 1980).

Three species introduced to California for research and field colonization for potential control of spider mites were morphologically indistinguishable from three California species. The introductions were tentatively identified as: *Neoseiulus chilenensis* (Dosse) collected in South America, considered by Athias-Henriot (1977) to be a junior synonym of *N. californicus* (McGregor); *Typhlodromus annectens* DeLeon, collected in Mexico; and *Phytoseiulus macropilis* (Banks), collected in the Cook Islands.

To have an additional criterion on which to base decisions regarding the identity of these species, we conducted cross-breeding experiments. The results reported herein help to clarify the identity and distribution of these three species.

Materials and Methods

The following insectary cultures were established, and crosses made: (1) *Neoseiulus "chilenensis,"* one stock originating from Urubamba, Cuzco Dept., Peru on avocado, and the other from Teno, Curico Prov., Chile on citrus, both collected in March 1983; (2) *N. californicus,* collected near Oxnard, CA on strawberry in April 1983, and crossed with the Peru stock in May 1983 and with the Chile stock in December 1983; (3) *Phytoseiulus macropilis,* collected in the Cook Islands on an unidentified tree in August 1981, and in Oceanside, CA on *Ricinus communis* in November 1981, crossed in December 1981; (4) *Typhlodromus annectens,* collected in Ocozocoautla, near Tuxtla Gutierrez, Chiapas, Mexico on avocado in February 1981, and in Carpinteria, Santa Barbara Co., CA in September 1981 on avocado, crossed in January 1982.

Crosses were conducted in the laboratory at temperatures of 23–25°C. Eggs or larvae from the stock cultures were isolated in 3.7-ml shell vials containing a layer of 2.5% agar at the bottom and closed with ventilated stoppers (McMurtry, 1980). Mites were reared to maturity on eggs and larvae of *Tetranychus pacificus* McGregor washed from bean plants (Scriven and McMurtry, 1971). The mature female phytoseiids were isolated in clean vials with fresh prey, and individual males from the appropriate cultures were added to each vial to initiate the desired cross. Each reciprocal cross consisted of 13–18 pairs. Control crosses (♀ × ♂ from the same culture) also were made. Vials were examined and eggs recorded for the first 3–6 days of oviposition. In the crosses involving *P. macropilis* and *T. annectens,* F_1 eggs or larvae were isolated in vials and reared to maturity and the females backcrossed to males of the same stock as the P_1 ♀.

Results

N. californicus × *N. "chilenensis."*—Reproductive compatibility was evident in crosses between the California population of *N. californicus* and both the Peru and Chile populations of *N. "chilenensis"* (Table 1). For unknown reasons, the oviposition rate was lower in the control crosses than in the California × Peru crosses. Moreover, 4 and 3 of the 6 females in the two control crosses failed to oviposit, but this was due to inadvertent pairing of 2 females rather than one individual of each sex.

Examination of series of specimens from Peru, Chile and California revealed

Table 1. Results of experiments crossing a California population of *Neoseiulus californicus* (CA) with populations of *N.* "*chilenensis*" from Chile (CH) and Peru (PE).

Cross ♀ × ♂	No. pairs	♀ ovipositing No.	♀ ovipositing %	$\bar{x}$ no. eggs/♀/day	Progeny sex ratio ♀:♂
CA × CH	15	14	93.3	1.78 ± 0.21[1]	1.24
CH × CA	15	13	86.7	1.44 ± 0.53	1.41
CA × CA	7	7	100	2.24 ± 0.33	1.76
CH × CH	7	7	100	1.33 ± 0.73	2.11
CA × PE	13	12	92.3	3.10 ± 1.7[2]	—
PE × CA	13	11	84.6	3.36 ± 1.9	—
CA × CA	6	2	33.3	1.72 ± 0.91	—
PE × PE	6	3	50.0	1.92 ± 1.8	—

[1] Mean ± SD for first 3 days of oviposition.
[2] Mean ± SD for first 4 days of oviposition.

no consistent differences in dorsal shield setal measurements or other characters such as the spermatheca, ventrianal shield and leg macrosetae.

In a previous study, mites of a stock from Valencia, Spain were crossed with a stock from Oxnard, CA, and no evidence of incompatibility was found (McMurtry and Mahr, unpubl.). These and the present studies support the contention of Athias-Henriot (1977) that *N. chilenensis* from South America is the same as *N. californicus* from California, Spain and France, and should be considered the junior synonym of *californicus*.

P. macropilis.—The results of the P_1 crosses and F_1 backcrosses revealed no incompatibility between the Cook Islands (MI) and California (MC) populations (Table 2). Progeny production was comparable to that of the controls in all cases. Although a lower percentage of the MI ♀ crossed with MC ♂ laid eggs, compared with those in the reciprocal cross, all but one of the (MI × MC) hybrid females laid eggs in the backcross experiment.

T. annectens.—Only 23% of the Mexico females (AM) paired with California

Table 2. Results of crossing experiments involving populations of *Phytoseiulus macropilis* from California (MC) and Cook Islands (MI).

Cross ♀ × ♂	No. pairs	♀ ovipositing No.	♀ ovipositing %	$\bar{x}$ no. eggs/♀/day[1]
		Parental crosses		
MC × MI	18	17	94.4	2.90 ± 0.76
MI × MC	18	11	61.1	2.36 ± 0.49
MC × MC	7	6	85.7	2.29 ± 1.13
MI × MI	8	7	87.5	2.89 ± 1.02
		F_1 backcrosses		
(MCMI) × MC	18	14	77.8	3.50 ± 1.16
(MIMC) × MI	17	16	94.1	3.78 ± 0.87
MC × MC	7	3	42.8	2.75 ± 2.41
MI × MI	6	5	83.3	3.10 ± 0.45

[1] Mean ± SD for first 4 days of oviposition.

Table 3. Results of crossing experiments involving populations of *Typhlodromus annectens* from California (AC) and Mexico (AM).

Cross ♀ × ♂		No. pairs	♀ ovipositing No.	%	$\bar{x}$ no. eggs/♀/day
			Parental crosses		
AC	× AM	15	7	46.7	1.91 ± 0.46[1]
AM	× AC	13	3	23.1	0.62 ± 0.08
AC	× AC	5	5	100	1.44 ± 0.22
AM	× AM	5	5	100	1.04 ± 0.17
			F_1 backcrosses		
(AC × AM)	× AC	12	12	100	1.69 ± 0.18[2]
AC	× AC	5	5	100	1.65 ± 0.85
AM	× AM	5	5	100	1.14 ± 0.42

[1] Mean ± SD for first 5 days of oviposition (7 days for AM × AC).
[2] Mean ± SD for first 6 days of oviposition.

(AC) males produced progeny, and the mean rate of oviposition was lower than that for the reciprocal cross. All of these progeny developed into males (Table 3). Nearly 50% of the AC ♀ paired with the AM ♂ reproduced, and at a rate at least as high as that of the females in the control crosses. Both ♀ and ♂ progeny were produced. F_1 hybrid ♀ backcrossed to AC ♂ all produced progeny of both sexes, and their mean oviposition rate was ca. 1.7 eggs/♀/day (Table 3).

The holotype of *T. annectens* (from Florida) is the smallest specimen (dorsal shield length 238 μm) examined by us and also by Chant and Yoshida-Shaul (1984). Setal lengths are also greater for all of our specimens (11 measured) than for the holotype. A consistent difference found between the California and Mexico specimens was in the length of the peritreme. The mean peritreme length for 12 CA specimens was 55 μm (range 43–70) and for 12 MX specimens it was 92 μm (84–112), compared to 94 for the holotype. The mean dorsal shield length was 288 μm for CA specimens (276–307, n = 12), and 272 μm for MX specimens (259–289, n = 15). Setal lengths varied little between the two populations, although there was no overlap between populations in lengths of 3 pairs of setae: CA specimens (n = 5) j5 42 (39–46), z3 40 (39–46), z5 42 (40–51); MX specimens (n = 6) j5 36 (33–38), z3 34 (31–37), z5 36 (34–37).

Because the females in one of the reciprocal crosses (CA × MX) produced progeny at a rate comparable to females in control crosses, including female progeny which proved to be fertile in the F_1 backcross, we consider the two populations to be conspecific. Specimens from other areas need to be examined to determine if there are some populations which have peritreme lengths that are intermediate between those of the CA and MX populations.

Discussion

These studies support the taxonomic literature indicating that *N. californicus* and *P. macropilis* have widespread distributions (Moraes et al., 1986). The former species is known from 3 continents, mainly in subtropical or tropical regions, and from many kinds of agricultural crops, including citrus, apple, grape, bean, cassava and strawberry. *P. macropilis* is common in the Neotropical region, extends into

California and Florida, and is known from various Pacific islands, as well as from Portugal, Canary Islands and Angola (Moraes et al., 1986). The closely related *Phytoseiulus persimilis* Athias-Henriot also was known from two continents (Kennett and Caltagirone, 1968) before it was used extensively in biological control programs and introduced intentionally to many countries, where it is now established (Moraes et al., 1986).

As *P. macropilis* occurs on many plants used by man, including sweet potato, taro, papaya, cassava, bean, strawberry and tomato, its extensive distribution might be attributed to human transport. Because the stock from the Cook Islands originated from mites found in colonies of an *Oligonychus* sp. on a tree, it was thought that this could be a biotype which, if established California, might be an effective predator of *Oligonychus punicae* (Hirst) on avocado. However, experimental mass releases of this predator did not result in significant suppression of *O. punicae* (McMurtry et al., 1984), and there is no evidence that permanent establishment has occurred in the release areas of southern California (unpubl. obs.).

T. annectens is known only from the New World, mainly from tropical and subtropical areas (Moraes et al., 1986). Collections from Ohio, U.S.A. and Prince Edward Island, Canada (Chant and Yoshida-Shaul, 1984) seem surprising in this context. In California, we have collected it only in coastal areas of San Diego and Santa Barbara counties.

The apparent absence of reproductive barriers between widely separated populations of *N. californicus* or *P. macropilis* suggests a relatively recent movement to new geographical areas or, alternatively, a relative stability of morphological and/or physiological characters related to mating and reproduction. Such stability cannot be suggested for the Phytoseiidae in general. For example, studies of *Euseius* species indicate the existence of numerous strains with varying degrees of incompatibility, as well as species with only subtle morphological differences (McMurtry, 1980; McMurtry et al., 1985; Congdon and McMurtry, 1985, 1986). With the exception of *Euseius finlandicus* (Oudemans), one of the few *Euseius* species occurring in temperate climates, intercontinental distribution apparently is rare in this genus. For example, each subtropical region of the world seems to have a different *Euseius* species on citrus (McMurtry, 1977). All of this suggests a degree of plasticity in the genus *Euseius* that is greater than that of other groups of Phytoseiidae.

Additional studies of this nature should lead to a better understanding of the biogeography and phylogeny of the Phytoseiidae.

Literature Cited

Athias-Henriot, C. 1977. Nouvelles notes sur les Amblyseiini. III. Sur le genre *Cydrodromus*: redefinition, composition (Parasitiformes, Phytoseiidae). Entomophaga, 22:61–73.

Chant, D. A., and E. Yoshida-Shaul. 1984. A world review of the *occidentalis* species group in the genus *Typhlodromus* (Acarina: Phytoseiidae). Can. J. Zool., 62:1860–1871.

Congdon, B. D., and J. A. McMurtry. 1985. Biosystematics of *Euseius* on California citrus and avocado with the description of a new species (Acari: Phytoseiidae). Internat. J. Acarol., 11: 23–30.

———, and ———. 1986. The distribution and taxonomic relationships of *Euseius quetzali* McMurtry in California (Acari: Phytoseiidae). Internat. J. Acarol., 12:7–11.

Kennett, C. E., and L. E. Caltagirone. 1968. Biosystematics of *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae). Acarologia, 10:563–577.

Mahr, D. L. 1979. California species of the *Typhlodromus pini* Chant species group (Mesostigmata: Phytoseiidae). Internat. J. Acarol., 5:213–230.

———, and J. A. McMurtry. 1979. Crossbreeding studies involving populations of *Typhlodromus citri* Garman and McGregor, *T. arboreus* Chant, and a sibling species of each. Internat. J. Acarol., 5:155–161.

McMurtry, J. A. 1977. Biological control of citrus mites. Proc. Int. Soc. Citricult., 2:456–459.

———. 1980. Biosystematics of three taxa in the *Amblyseius finlandicus* group from South Africa, with comparative life history studies (Acari: Phytoseiidae). Internat. J. Acarol., 6:147–156.

———. 1982. The use of phytoseiids in biological control: progress and future prospects. *In* Recent advances in knowledge of the Phytoseiidae. Div. Agr. Sci., Univ. Calif. Publ. 3284.

———, M. H. Badii, and B. D. Congdon. 1985. Studies on a *Euseius* complex on avocado in Mexico and Central America, with a description of a new species (Acari: Phytoseiidae). Acarologia, 26: 107–116.

———, H. G. Johnson, and M. H. Badii. 1984. Experiments to determine effects of predator releases on populations of *Oligonychus punicae* (Acarina: Tetranychidae) on avocado in California. Entomophaga, 29:11–19.

———, D. L. Mahr, and H. G. Johnson. 1976. Geographic races in the predaceous mite, *Amblyseius potentillae* (Acari: Phytoseiidae). Internat. J. Acarol., 2:23–28.

Moraes, G. J. de, J. A. McMurtry, and H. A. Denmark. 1986. A catalogue of the mite family Phytoseiidae: references to taxonomy, synonomy, distribution and habitat. EMBRAPA-DDT, Brasilia, 353 pp.

Scriven, G. T., and J. A. McMurtry. 1971. Quantitative production and processing of tetranychid mites for large-scale testing or predator production. J. Econ. Entomol. 64:1255–1257.